 doi:10.20944/preprints201802.0040.v2

Hard Coating is Because of Oppositely Worked Force-Energy Behaviors of Atoms

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Abstract –Coatings of suitable materials of thickness of few atoms to several microns on certain substrate is the basic need of society and attend the regular attention of scientific community working in different domains; decorative and protective coatings, transparent and insulating coatings, coating medical implants and surgical instruments, coatings for drug delivery and security purposes, ultra-precision machine coatings, coating cutting tools, coatings for MEMS and NEMS, and so on. Different coatings develop under significant composition of certain nature atoms where their force-energy behaviors while certain transition state provide the provision for electron in outer ring of gas atom to clamp another energy knot clamped unfilled state in the outer ring of solid atom. Under certain process conditions, different nature atoms upto a certain extent oppositely-switch force-energy behaviors to the ones which possess those behaviors originally where they locate ground points at common mid-points of accommodating levels resulting into grasp binding. Because of adjusting expansion-contraction of clamped energy knots to electrons under different potential energy as per exerting orientational force of gravitation-levitation behaviors, different nature atoms develop structure at near ground surface substrate termed as hard coating, which is known since antiquity. On arresting different nature atoms under their binding at nearly oppositely-worked force-energy, non-conservative energies of ground surface are involved to engage the non-conservative forces exerting their neutral behavior viable at electron level. Different properties and characteristics of hard coatings such as hardness, adhesion, roughness, friction coefficient, resistivity and morphology-structure are emerged as per order of rescued force-energy of their structure. Here, hard coatings invent science opening to several new areas.

Keywords: Hard coating; TiN; Atomic nature; Expansion-contraction; Potential energy; Force-energy behaviors; Ground point; Structure evolution

1. Introduction

Hard coatings are the integral part of scientific research along with their technological advances. It is learnt routinely that marketable hard coatings for different usages are involved in different sorts of materials and deposition technique. In this context, several materials and deposition techniques are available in the literature discussing and explaining both deposition history and application of deposited coatings at suitable substrates and tools. In coatings, a minute deposited quantity of materials over less-important (not viable) material solves the purpose by giving value-added results, and often, in an astonishing way.

A variety of techniques are involved to deposit different sorts of hard coatings at the surface of suitable substrates. Coatings are mainly employed with two targeted approaches; in the first case, the potential use of external coated part, which is not subjected to a great deal in the uncoated case and in the second case, potential use of internal surface where inner uncoated surface of material was not the subject of great concern but on coating, it became a great deal. Overall, coating the surface of certain substrate results into deliver its different behavior of functioning.

Atoms of electronic transition do not elongate and those belonging to inert gases split under the excess propagation of photons characteristic current [1]. A neutral state silicon atom transformed heat energy into photon energy as discussed elsewhere [2]. Depending on the nature of certain solid behavior atoms, they evolve different dimension and format structures as per the nature of their electronic gauge where conservative forces involved to execute confined inter-state electron-dynamics [3]. The origins of atoms of certain elements to be in gas state and certain elements to be in solid state are discussed elsewhere [4]. However, a carbon atom originating its completely different physical behavior is under the involvement of characteristic energy where confined inter-state dynamics of electron is under the engagement of non-conservative forces and so in the case of evolving different sorts of structure as discussed elsewhere [5]. Depending on the atomic behavior of tiny-sized particles their role for nanomedicine can either be good or harmful [6].

Formation of different tiny particles under varying conditions of the process shows the attaining of different dynamics of their atoms [7]. A monolayer triangular-shaped tiny particle was considered as the model system discussing the elongation behavior of one-dimensional arrays of gold atoms and their conversion into structure of smooth elements under the joint application of surface format force and travelling photons of adequate wavelength [8]. At suitable precursor concentration, many tiny particles shape-like equilateral triangle developed as discussed elsewhere [9]. Shapes of tiny sized particles and large sized particles were controlled under the application of different ratios of pulse OFF to ON time [10]. Particles of different anisotropic shapes developed in less than millisecond time [11]. Developing tiny sized particles of certain shape tapped in silver solution and binary composition in addition to gold solution [12]. Predictor packing in developing gold particles is discussed elsewhere [13] where certain levels of force-energy behaviors control their shapes.

Different behaviors of tiny grains carbon films registered under Raman spectroscopy and energy loss spectroscopy [14]. Switching morphology-structure of grains and crystallites under a bit altered locally operating parameters in developing carbon films is discussed elsewhere [15]. Under varying chamber pressure, a discernible change in the morphology and growth rate of carbon films was observed as discussed elsewhere [16].

Depositing TiN coatings on different substrates under varying process conditions while employing a technique known as ‘cathodic arc physical vapor deposition’, a different morphology-structure along with hardness, surface roughness, friction coefficient, adhesion strength and overall performance of coated tools were studied in different studies given elsewhere [17-28]. In addition to those, there are several other available studies in the literature targeting TiN coating along with processing technique and analysis [29-36]. In addition to TiN coating, studies on different types of hard coatings which were developed under various employed conditions are also available [37-48]. The basic idea discussed in those studies is related to the properties and characteristic of deposited coatings, which are subjected to the change of process parameters, type of material and processing approach, mainly.

The prosperous assembling of colloidal matter into meaningful structure will result into deal atoms and molecules as tomorrow's materials [49] and understanding in the individual dynamics of tiny-sized particles formation is essential before enabling their assembling to useful large-sized particles [50].

In addition to the discussed scientific details of hard coatings, coatings are in the way to express relation between their counterparts. This study reports the fundamental aspect of developing hard coatings with emphasis on TiN coating while depositing on a high-speed steel (HSS) disc in random arc-based physical vapor deposition technique. The aim of this work is to present the fundamental aspect of depositing hard coating, in general, and investigating mechanism of developing TiN coating, in specific.

2. Experimental details

Samples of HSS discs were utilized for the deposition of TiN coating in a commercially available coating unit known as 'cathodic arc physical vapor deposition', which is termed as 'random arc-based physical vapor deposition' in the present study. After necessary cleaning, the samples (diameter: 10 mm, thickness: 6 mm) were loaded in the coating system mark Hauzer Techno Coating (HTC) 625/2 ARC. The complete deposition procedure along with metallographic process of samples has been described earlier as given elsewhere [28].

Surface morphology and interface studies were done using FE-SEM (Model LEO-1525). The thickness of the deposited coatings was measured by using the application of FE-SEM under fracture cross-sectional image. Prior to go for TiN coating, an interlayer of Ti was deposited for 15 minutes time to enhance the adhesion strength of the following TiN coating. At start of depositing inter-layer, the chamber pressure was 5×10^{-6} mbar. While depositing inter-layer, 50 sccm nitrogen gas flow rate was maintained by mass flow controller meter. To deposit TiN coating, substrate temperature was maintained at 300°C where N gas flow rate was 250 sccm. The bias voltage was 50 volts where rotational speed of the substrate holder was set 60%. The current to ignite arc for ejecting Ti-atoms from the metallic target was 100 Amps. Total duration of the deposition was 90 minutes.

3. Results and discussion

Figure 1 (a) shows surface morphology of deposited TiN coating on HSS disc where coating surface is partially covered with macrodroplets (MDs), size ranges from few hundred of nanometers to few microns. The distribution of MDs is uniform throughout the surface. A large sized macrodroplet (MD) in the central vicinity shows the mapping of the region comprising atoms of different elements where the concentration of both atoms related to Ti and N elements along with their scale of distribution is identified. There are several studies studying the reduction of MDs under varying the process parameters in cathodic arc PVD along with different employed strategies [17-20, 23-25].

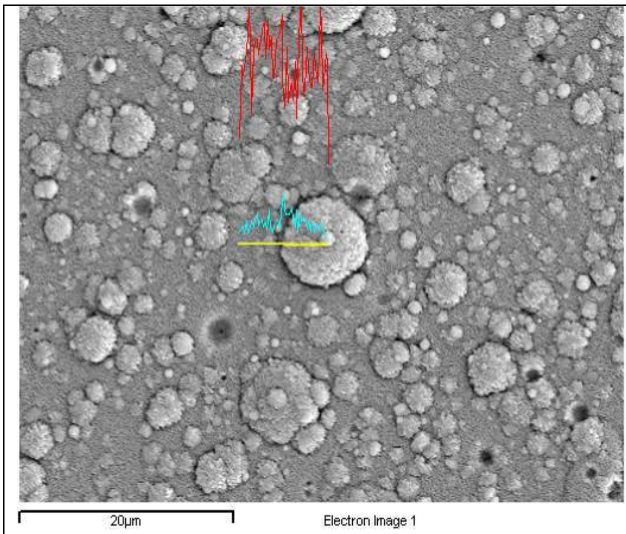

Figure 1 (a): Topography view of TiN coating on HSS

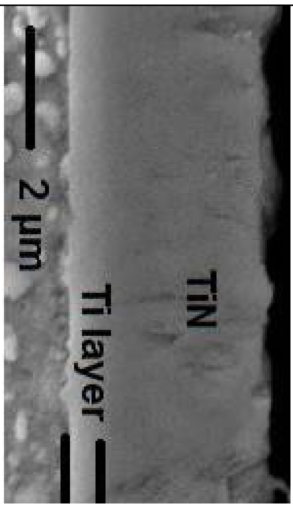

Figure 1 (b): Titanium interlayer in few hundred of nanometers shows contrast to TiN coating deposited in thickness ~4 µm (a cross-sectional view of coating prepared under metallographic cross-sectioning procedure)

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Figure 1 (b) shows fractured cross-sectional view of the coating where initially deposited Ti layer shows thickness less than one micron. Atoms of Ti-interlayer first adhere to surface atoms of substrate under the favorable nature of binding. Substrate surface comprises different elements like W, Mo, Cr, V, C, Fe, etc. to bind Ti-atoms as discussed elsewhere [17, 24]. Thus, Ti-atoms bound to substrate surface by introducing the favorable conditions of depositing TiN coating. In this context, the nature of substrate can possess different elements where their different force-energy behaviors can introduce appreciable binding to the depositing atoms resulting into produce value-added features of the resulted coating. Adhesion strength of TiN coating deposited under certain conditions in random arc-based PVD system is discussed elsewhere [26, 28].

Figure 2 shows the mapping of Ti-atoms available in TiN coating at point of MD (shown in Figure 1a) in the form of histogram, which is around 70% in its content. This indicates that the area (volume) covered by Ti-atoms in the TiN coating at top front surface not only contained 70% of the content of metallic element but the distribution of atoms in MD also remained dense and uniform. This also indicates that that MD contained very less concentration of N-atoms.

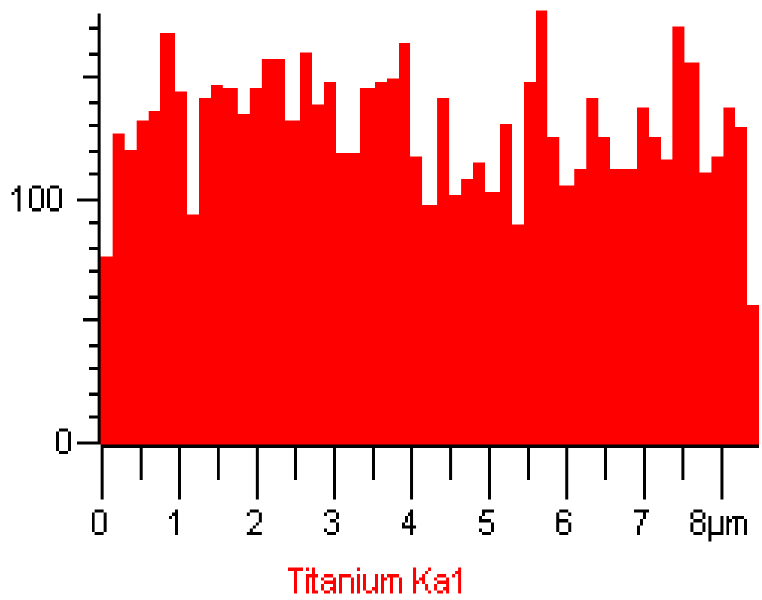

Figure 2: Mapping of Ti-atoms distribution along with the ratio of content

Figure 3 represents the mapping of N content in TiN coating in the form of histogram showing around 30% of contained area (volume) at the central point of MD as shown in Figure 1 (a). This indicates that the area (volume) covered by N-atoms in the TiN coating at top front surface not only contained 30% of content but also contained uniform distribution, however, not in the dense manner. This indicates that that MD contained approximately three times less concentration of N-atoms as compared to Ti-atoms.

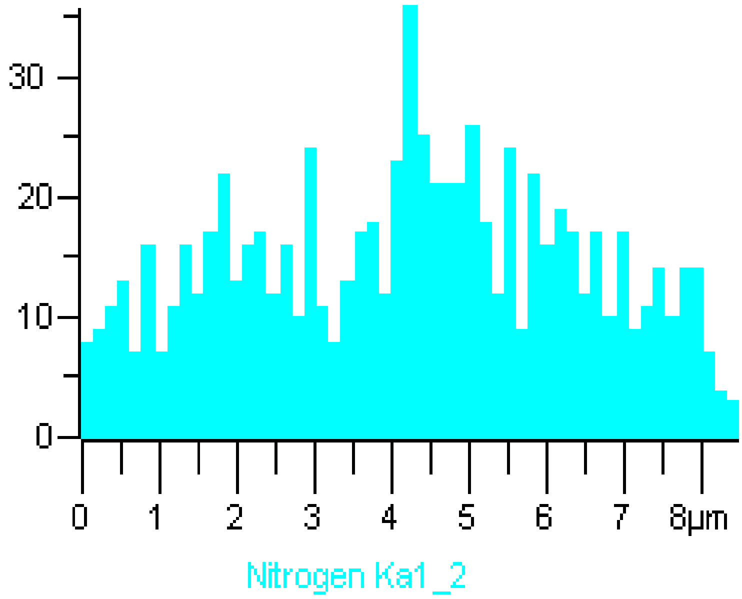

Figure 3: Mapping of N-atoms distribution along with the ratio of content

On incorporating the gas atoms, metallic atoms become poor in conduction where the resulted coatings work as nearly an insulator and enhanced field emission characteristics of propagating photons characteristic current is interrupted, which is the result of non-uniform inter-state electron gap in the atoms dealing irregular structures or ordered structure within the short-range order. In this context, the incorporation of N-atoms built the bridges through their electron states all around the Ti-atoms resulting into lower the propagation of photonic current and further detail regarding inter-state electron gap is given elsewhere [1]; the propagation of current no more requires the band gap between conduction band and valence band to explain the science of semiconductor materials or others.

At high concentration of N-atoms, a random arc is steered to eject Ti-atoms both in atomic form and tiny-sized cluster (droplet) form depending on the nature of Ti targets along with employed conditions of physical vapor deposition system. In random arc-based PVD system, atoms of Ti (or other metallic nature atoms) are ejected from the surface of different shaped targets where arc is utilized to supply the energy a bit in non-uniform manner depending on the strength of applied field per unit area (or volume). The basic layout of ejecting Ti-atoms and entering N-atoms to deposit TiN coating is sketched in estimation as shown in Figure 4.

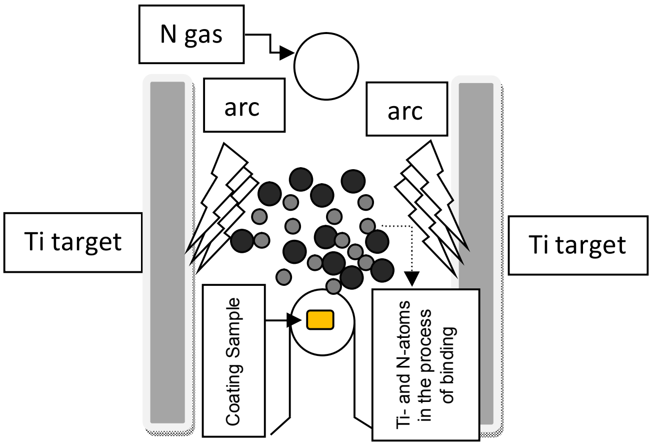

Figure 4: The basic layout of depositing Ti-atoms and N-atoms to evolve TiN coating at HSS substrate

In different coating technology of deposition-based technologies, regardless of that, required numbers of atoms per unit area or volume are depositing under certain tailored parameters, their involved energy is based on their individual attained dynamics, and electron-dynamics is the key to determine certain nature of their evolving structure and in terms of gaining uniformity in the order. However, it appears that formation of TiN structure in order of any homogeneity is within short-range order. Thus, the deposited coatings mainly deal the mixed behavior of structure within the short-range ordering of constituted atoms. Each Ti-atom only occupies two electrons in the outer ring. This low number of filled states allows the Ti-atom to occupy many unfilled states having non-occupancy of electrons. The states of non-occupant electrons are remained mainly at above east-west poles in a Ti-atom from both left and right sides. Because atoms of Ti element are belonged to grounded format where electrons of filled states in the outer ring are to be remained at below their east-west poles along the south-pole while

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dealing their original solid behavior. On the other hand, five filled states in outer ring of N-atom allow less number of unfilled states in the outer ring. In this context, a N-atom contains several filled states in outer ring where majority of the electrons (filled states) are expected to be at above the east-west poles along the north pole (in each dedicated state). This is because of the gas nature of N-atom and further detail is given elsewhere [4]. Therefore, several unfilled states (in outer ring) of Ti-atom provide provision to work for filled states (in outer ring) of the N-atom where targeted electron (of gas atom) is clamped by another clamping of energy knot (of solid atom). The double-clamping of energy knot to the electron of N-atom is by means of energy knot clamping unfilled state of the Ti-atom. But the mechanism of double clamping of energy knot by the electron is by means of suitable transition of electrons of both differently nature atoms. Atoms when in certain transition state adjust potential energy of their electrons as per dealing the orientational force of nature as discussed elsewhere [4, 5]. Therefore, two different nature atoms (Ti and N) develop affinity in terms of strong binding due to intrinsically dealing different nature of forces as per orientational force of their electrons. Here, the characteristic energies available at common mid-points of bound atoms at substrate (at ground surface) secure the binding of atoms by incorporating in between the minor left regions between electrons and their clamped energy knots, but in the non-conservative manner to affirmative the structure of opposite nature atoms (gas and solid).

Ti metal is known in metallic character where filled state electrons keep their atoms grounded under the maximum gravitational force where the maximum expansion of their clamped energy knots take place, also. Thus, electrons of Ti-atoms keep original (auxiliary) ground point at below ground surface in the normal environment. On the other hand, a N-atom belongs to gas behavior, which remains in the air under the engagement of space format force exerting under the neutral behavior, thus, its electrons keep original (auxiliary) ground point at above ground surface. The electrons of N-atoms keep their ground point at above ground surface because of the maximum contraction of their clamped energy knots under the maximum levitational orientational force. Therefore, in their joint deposition while employing a suitable coating technology unit, which is meant for this job, electron in outer ring of N-atom deal affinity in terms of benefiting another clamp of energy knot clamping by the unfilled state in outer ring of Ti-atom. Held another clamping of the energy knot by the electron of original gas behavior bound the atom of original solid behavior as energy knot of its unfilled state in the outer ring has been engaged resulting into deal natural (original) sort of binding between two oppositely behavior atoms where they search ground point neither at above ground surface nor at below ground surface. In the search of attaining their ground points, they mutually get ready for the common ground point at the surface of depositing substrate, which is nearly become at mid-point of two different ground points; at above ground surface (in gas atoms) and at below ground surface (in solid atoms). Under the tailored process parameters of deposition, atoms of hard coating deal high hardness of resulted coating where maximum ordering of different nature transition state atoms is due to higher ordered in attained mid-points of two differently nature bound atoms.

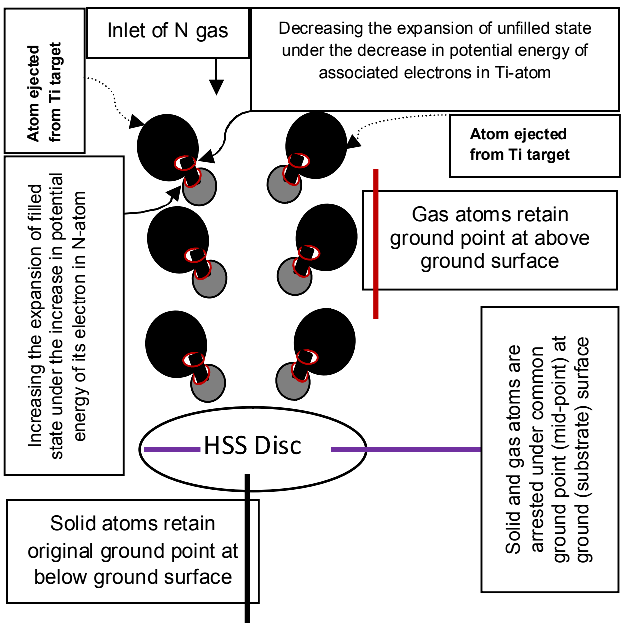

Figure 5: Mechanism of double clamping of energy knot to electron in two different nature atoms

The electrons of N-atoms deal double clamping of energy knots while orientating to unfilled states of Ti-atoms where gas state atoms are being uplifted while solid ones are being grounded. Suitable transition state gas atoms deal double clamping of energy knots to their targeted electrons as their orientations become favorable. On aligning such orientated electrons of N-atoms for visualizing their orientational gravitational force (while forcefully grounding) through hollow regions of energy knots clamped unfilled states of Ti-atoms (while forcefully uplifting where also visualizing their orientational force but a levitational force this time) result into deal double clamping of energy knots; one energy knot of electron belonging to its own state (of N-atom) and second energy knot belonging to unfilled state of Ti-atom. This double clamping of energy knots to electron of N-atom ground forcefully by the grounding force of Ti-atom through its certain clamped energy knot to unfilled state as shown in Figure 5. In the instant of attempting the gravitation behavior of electrons in gas atoms where their clamping energy knots deal expansion, the work is being done on their atoms, hence, that work is positive. On the other hand, the work is being done by the atoms of solid behavior where clamping energy knots deal contraction under exerting levitational force of their electrons, hence, that work is negative.

Because, solid atom dealt tensing of force in terms of surround environment, which is due to the grounded ground point under the fully gravitized behavior of its electrons, thus, gained their maximum potential energy where their clamped energy knots also dealt the maximum expansion. Atoms of both gas and solid engage conserved energies under their original behaviors where increasing and decreasing their energies, respectively, under the matching orientational force results into their binding; in gas atoms when dealing the certain transition state their electrons increase their gravitational orientational force under forcefully decreasing the levitational orientational force, but in solid atoms when dealing the certain transition state their electrons decrease their gravitational orientational force under forcefully increasing the levitational orientational force. This bring the certain electron in outer ring of N-atom to orientate under the fixed force of north-south pole to energy knot clamping unfilled state in outer ring of Ti-atom for binding, hence, devising the unit (primitive cell) of hard coating.

In the case of a hard-TiN coating both solid atoms and gas atoms deal their opposite phenomena in the description. As, in one case, Ti-atoms were reached to substrate surface where they were held by them in the form of deposition. In the second case, N-atoms entered in the inside hollow space of ejecting Ti-atoms under the inserted pressure of downward force where instead of instating the original ground point (which is at above ground surface), they are being arrested at ground surface by Ti-atoms. This results into deal double clamping of energy knot by the electron of gas atom under the disposal of clamping energy knot of unfilled state of solid atom when accommodating the level of ground points where instead of restoring their original state behaviors at naturally designated ground points, they are arrested under the available provision of clamping another energy knot (of solid atom) to already clamped energy knot electron (of gas atom). This results into present the increased elastic behavior and the decreased plastic behavior of metallic nature depending on the order of successful rate of double clamping of energy knots for electrons of gas atoms.

The similar sort of mechanism is being anticipated in bi-metallic composition with gas behavior atoms, for example, TiAlN. Again, low measured-hardness coating of chromium nitride (compared to TiN) involves the same mechanism of binding their different nature atoms where high probability is involved as Cr-atom contains many unfilled states in the outer ring (compared to Ti-atom). That's way CrN coating deals low surface roughness as compared to TiN coating [28] because of greater level of homogeneity of binding atoms while evolving structure; probability of binding atoms becomes higher. A similar approach may be validated to explore the science of other hard, moderate hard and even less hard (soft and porous) coating materials. A different originating science mechanism may be anticipated in the case of TiCN coating where involving the same mechanism of double clamping of energy knot to possible electrons of two different metallic nature atoms. Arresting of gas state behavior atoms with metallic behavior atoms endorse the behavior of force dealing by the electrons under the adjustment of expansion or contraction of clamping energy knots where gaining (increase) or losing (decrease) of potential energy under fixed orientational forces of their south and north poles are involved, respectively. A photon wavelength in the characteristic current is discussed elsewhere [1]. A unit-photon and an overt photon are discussed elsewhere [2]. The origin of different elements of gas state atoms and solid atoms is discussed elsewhere [4]; inter-changeable force-energy behaviors of different nature atoms are discussed along with structure of different atoms. Atomic structure and binding of identical state carbon atoms are discussed elsewhere [5].

4. Conclusions

This is the provision of solid atom under the transition state to allocate energy knot of unfilled state in outer ring to hold another clamp of energy knot to electron in the outer ring of gas atom under the transition state too. The arresting of gas state atoms while the ground point is just at ground surface instead of the ground point at above ground surface increase the gravitational orientating force while decreasing the levitational orientating force where potential energy of their electrons is increased under the expansion of their clamped energy knots. The arresting of metallic nature atoms while the ground point is just at ground surface instead of the ground point at below ground surface decrease the gravitational orientating force where potential energy of their electrons is decreased under the contraction of their clamped energy knots. This results into the binding of two different nature atoms at a common ground point, which is the mid of ground point of gas atom and solid atom, thus, developing a structure for the hard coating.

The underlying science of developing hard coating is in the manner that atoms of solid behavior perform work (negative) when undertaking the certain transition state as the atoms attain ground point at the level of ground surface (instead at below ground surface) and atoms of gas behavior perform work (positive) as the atoms attain ground point at level of ground surface (instead at above ground surface). In depositing hard coating, gas atoms shift levitational orientational force of their electrons to gravitational orientational force where expansion of contracted clamping energy knots to electrons takes place, whereas, solid atoms shift gravitational orientational force of their electrons to levitational orientational force where the contraction of expanded clamping energy knots takes place.

Transition metals govern hard features of coating under affinity to gas atoms because, one is dealing the force of grounded format and other is dealing the force of space format resulting into locate the common ground point having mid-point at level of ground surface; between below ground surface and above ground surface. The electrons in outer ring of gas atoms (N-atoms) depositing on the substrate to develop TiN coating when deal another clamping of energy knots clamped unfilled states in outer ring of solid atoms (Ti-atoms) from the rear-side where they attempted forcefully the gravitational orientating force under the increased potential energy. Such arrested features remained engaged once gas transition atom binds to solid transition atom.

Appropriate vacuum conditions and high power enhance the hardness level of deposited coatings. Hard coatings introduce certain properties and application due to the developing of non-regular structure where non-conservative energies involve engaging non-conservative forces of their electrons exerting neutral behavior. But, they are not overwhelming forever where force-energy behaviors are changed largely, and lifetime of hard coatings depends on their developing strategies along with the scope of their application and usage. In line with this, deposition of hard coatings along with other ones requires the re-consideration in explaining their science and technology.

Acknowledgements:

Mubarak Ali is obliged to Malaysian Government for awarding scholar of PhD study (2004-07) under award letter No. JPA(L) KD333487 and Government of Pakistan (MoST) for granting the study leave. He is also grateful to Malaysian colleagues at AMREC, SIRIM Berhad and at UTM Johor for their kind hospitality. Special thanks to Professor Dr. Ali Ourdjini for reviewing the work at several times and constructive feedback while studying at UTM who is now with the University of Ottawa, Canada.

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